REPORT DOCUMENTATION PAGE

AFRL-SR-AR-TR-04-

0042

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED
15 OCT 98 - 14 OCT 01

4. TITLE AND SUBTITLE
MODELING AND CONTROL OF NONLINEAR OPTICAL WAVELENGTH CONVERSION

5. FUNDING NUMBERS
F49620-99-1-0016

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9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NM
4015 Wilson Blvd, Room 713
Arlington, VA 22203-1954

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
F49620-99-1-0016

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A key issue for high power lasers in general and for high-power OPOs As that the intense laser light tends to heat the gain medium (i.e. the crystal) as some of the light is absorbed. We therefore developed a numerical model to simulate thermal effects in optical parametric oscillators. First, we implemented a wavelength conversion code using radially-symmetric Hankel transforms to speed up the simulations. Many comparisons of different Hankel and fast Hankel trans forms were done to determine which would be the best one to use. Once this was working we then added thermal effects. Because of the tremendously disparate timescales an algorithm was developed to accelerate the numerical simulation of the thermal evolution. The results of these studies also allowed several potential improvements to this acceleration algorithm to be identified. Note that without specific algorithms to speed up the simulations, numerical run times would be prohibitive.

20040203 046

14. SUBJECT TERMS

15. NUMBER OF PAGES
4

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT

18. SECURITY CLASSIFICATION OF THIS PAGE

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

Modeling and Control of Agile-Wavelength Laser Sources
AFOSR FY99 Grant F49620-99-1-0016

Final Technical Report
1 September 98 -- 15 January 02

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OBJECTIVES

Air Force flight missions expose pilots and aircraft to attack by guided missiles, and the development of countermeasures that decrease the risk associated with these threats is therefore a central issue. Guidance systems for anti-aircraft weaponry are often based on infrared sensing technology. To jam such systems, a key enabling component for countermeasures technologies is a high power, tunable laser system that can be packaged to work robustly on an aircraft.

In the following report we describe work done at Northwestern by and under the guidance of William Kath and Greg Luther to support modeling efforts of tunable lasers at Wright Patterson Air Force Base. Several trips to Wright Labs were made to discuss ongoing projects and support needs with the research group headed by Dr. Ken Schepler and collaborative work performed at the University of Dayton under the direction of Prof. Peter Powers. It was found through these visits that key issues were numerical and analytical modeling of optical parametric oscillators (OPO) that use quadratic crystals with periodic polling to quasi-phase-match conversion of the pump lasers. In particular, important issues were the speed and efficiency of numerical algorithms, and the modeling of transverse, thermal, and photorefractive effects.

ACCOMPLISHMENTS/NEW FINDINGS

A key issue for high power lasers in general and for high-power OPOs is that the intense laser light tends to heat the gain medium (i.e. the crystal) as some of the light is absorbed. We therefore developed a numerical model to simulate thermal effects in optical parametric oscillators. First, we implemented a wavelength conversion code using radially symmetric Hankel transforms to speed up the simulations. Many comparisons of different Hankel and fast Hankel transforms were done to determine which would be the best one to use. Once this was working we then added thermal effects. Because of the tremendously disparate timescales an algorithm was developed to accelerate the numerical simulation of the thermal evolution. The results of these studies also allowed several potential improvements to this acceleration algorithm to be identified. Note that without specific algorithms to speed up the simulations, numerical run times would be prohibitive.

OTHER EFFORTS

Cascaded Optical Parametric Oscillators

In earlier work at Wright Labs and at Phillips Lab a cascaded OPO was developed. This system had two crystals in the laser cavity. The pump laser is converted in the first crystal and the products are then further converted in the second crystal. The hope here is to generate laser light at wavelengths that are typically not obtainable using standard materials with a single stage of conversion. The second crystal complicates the design, so at the suggestion of scientists at Wright Labs and the University of Dayton we considered systems that would accomplish the same five-wave interaction in a single crystal.

Importance Sampling for Polarization Effects in Optical Fibers

We developed a new method to simulate rare events due to random polarization effects in optical fibers. The method allows low probability events to be simulated much more efficiently than with traditional methods.

PERSONNEL SUPPORTED

* Faculty

William L. Kath, Northwestern University
Gregory G. Luther, Northwestern University and Corning Incorporated

* Post-Docs

Dr. Gino Biondini

* Graduate Students

Mr. Sandeep Bhatt
Mr. Richard Moore

* Other (please list role)

PUBLICATIONS

* Journals

1. G. Biondini, M. J. Ablowitz and S. Blair, Nonlinear Schrödinger equations with mean terms in non-resonant multi-dimensional quadratic materials, Phys. Rev. E 63, 046605: 1-15 (2001)

2. G. Biondini, M. J. Ablowitz and S. Blair, Multidimensional optical pulses in non-resonant quadratic materials, Math. Comp. Simul. 56, 511-519 (2001)

3. G. Biondini, W. L. Kath and C. R. Menyuk, A method for calculating outage probabilities due to polarization-mode dispersion using importance sampling, in Optics in 2001 (annual selection of articles that highlights the most important findings in optics), Optics and Photonics News, December 2001.

4. G. G. Luther, M. S. Alber, J. E. Marsden and J. M. Robbins, Geometry and control of Chi^2 processes and the generalized Poincare sphere, J. Opt. Soc. Am. B, vol. 17 (2000), pp. 932-941.

5. M. S. Alber, G. G. Luther and C. A. Miller, On New Soliton-type Solutions of Equations Associated with the Coupled KdV System, J. Math. Phys., vol. 41 (2000), pp. 284-316.

* Conferences

Refereed:

M. S. Alber, G. G. Luther, J. E. Marsden, and J. M. Robbins, Geometry and Control of Three-Wave Interactions, Fields Institute proceedings of the Arnold fest. A celebration of V.I. Arnold's 60'th Birthday.

Unrefereed:

R. O. Moore, G. Biondini and W. L. Kath, Thermal effects and modal competition in continuous-wave optical parametric oscillators, Proceedings of the Optical Society of America 2001 Annual Meeting.

* Theses

1. A study of optical devices with parametric gain, Richard O. Moore, Ph.D. thesis, Northwestern University, December, 2001.

* ACCEPTED

* Journals

R. O. Moore, G. Biondini and W. L. Kath, Self-induced thermal effects and modal competition in continuous-wave optical parametric oscillators, J. Opt. Soc. Amer. B, to appear.

INTERACTIONS/TRANSITIONS

* Participation/Presentations At Meetings, Conferences, Seminars, Etc

1. R. O. Moore, G. Biondini and W. L. Kath, Thermal effects and modal competition in continuous-wave optical parametric oscillators, Optical Society of America 2001 Annual Meeting.

2. W. L. Kath, Modeling of quasi-phase-matched optical wavelength conversion, Workshop on Nonlinear Optics, Arizona Center for Mathematical Sciences, University of Arizona, September, 2000.

3. G. G. Luther, ``Controlling resonant wave interactions to enhance frequency conversion in nonlinear optics," Fifth SIAM Conference on Applications of Dynamical Systems, Snowbird, Utah, May 23 - 27, 1999.

4. G. G. Luther, ``Geometry and Control of Resonant Wave Interactions in Nonlinear Optical Systems," Michigan Interdisciplinary Mathematics Meeting II, Optimization, Algorithms and Control, Department of Mathematics, University of Michigan, Ann Arbor, Michigan, May 6 - 8, 1999.

5. G. G. Luther, ``Understanding control strategies for resonant waves interactions using geometric techniques," Interdisciplinary Seminar in Nonlinear Science, Northwestern University, Evanston, Illinois, April 16, 1999.

6. G. G. Luther, ``Understanding control strategies for nonlinear waves using geometric and spectral techniques," Photonic Modeling and Process Engineering Department, Corning Incorporated, Corning, New York, March 25, 1999.

7. G. G. Luther, ``Geometry and control of resonant wave interactions to improve the nonlinear response of optical materials," Department of Mathematics and Statistics and Center for Advanced Studies, Topics in Stability Theory Seminar, University of New Mexico, March 10, 1999.

8. G. G. Luther, ``Geometry and control of parametric interactions: generalization of the Poincare sphere," Annual Meeting of the Optical Society of America, Baltimore Convention Center, Baltimore, Maryland, October 4 - 9, 1998.

9. G. G. Luther, ``Geometry of large nonlinear phase shifts for engineered second-order nonlinear-optical processes," Annual Meeting of the Optical Society of America, Baltimore Convention Center, Baltimore, Maryland, October 4 - 9, 1998.

NEW DISCOVERIES, INVENTIONS, OR PATENT DISCLOSURES

HONORS/AWARDS